IN-PLACE DENSITY OF BITUMINOUS MIXES USING THE NUCLEAR MOISTURE-DENSITY GAUGE

FOP FOR WAQTC TM 8

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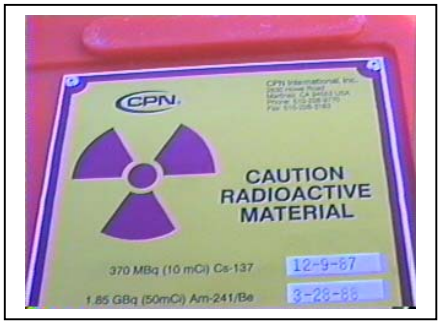
Significance

The final in-place density of roadway pavement is critical to the quality and longevity of a highway project. Low-density material will lead to excessive deflection under load and/or permanent deformation.

This procedure provides a rapid, nondestructive technique for determining the in-place density of compacted bituminous mixes. It can be used to establish the proper rolling effort and pattern to achieve the required density. The non-destructive nature of the test allows repetitive measurements to be made at a single test location between roller passes.



Caution!

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Scope

This test method describes a test procedure for determining the density of bituminous mixes by means of a nuclear gauge employing either direct transmission or backscatter methods. Correlation with densities determined under the FOP for AASHTO T 166 is required by some agencies.

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Apparatus

- Nuclear density gauge with the factory matched standard reference block.
- Drive pin, guide / scraper plate, and hammer for testing in direct transmission mode.
- Transport case for properly shipping and housing the gauge and tools.
- Instruction manual for the specific make and model of gauge.

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Nuclear gauge

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Filler on pavement

- Radioactive materials information and calibration packet containing:
  - Daily Standard Count Log
  - Factory and Laboratory Calibration Data Sheet
  - Leak Test Certificate
  - Shippers Declaration for Dangerous Goods
  - Procedure Memo for Storing, Transporting and Handling Nuclear Testing Equipment
  - Other radioactive materials documentation as required by local regulatory requirements.

Material

- Filler material: Fine graded sand from the source used to produce the asphalt pavement or other agency approved materials.

Radiation Safety

This method does not purport to address all of the safety problems associated with its use. The gauge utilizes radioactive materials that may be hazardous to the health of the user unless proper precautions are taken. Users of this gauge must become familiar with the applicable safety procedures and governmental regulations. All operators will be trained in radiation safety prior to operating nuclear density gauges. Some agencies require the use of personal monitoring devices such as a thermo luminescent dosimeter or film badge. Effective instructions together with routine safety procedures such as source leak tests, recording and evaluation of personal monitoring device data, etc., are a recommended part of the operation and storage of this gauge.

Calibration

11 Calibrate the nuclear gauge as required by the agency. This calibration may be performed by the agency using manufacturer's recommended procedures or by other facilities approved by the agency. Verify or re-establish calibration curves, tables, or equivalent coefficients every 12 months.

Standardization

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1. Turn the gauge on and allow it to stabilize (approximately 10 to 20 minutes) prior to standardization. Leave the power on during the day's testing.
2. Standardize the nuclear gauge at the construction site at the start of each day's work and as often as deemed necessary by the operator or agency. Daily variations in standard count shall not exceed the daily variations established by the manufacturer of the gauge. If 13 the daily variations are exceeded after repeating the standardization procedure, the gauge should be repaired and or recalibrated.
3. Record the standard count for both density and moisture in the Daily Standard Count Log. The exact procedure for standard count is listed in the manufacturer's Operators Manual.

Note 1: New standard counts may be necessary more than once a day. See agency requirements.

Test Site Location

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1. Select a test location(s) randomly and in accordance with agency requirements. Test sites should be relatively smooth and flat and meet the following conditions:
   a. At least 10 m (30 ft) away from other sources of radioactivity
   b. At least 3 m (10 ft) away from large objects
   c. If the gauge will be closer than 600 mm (24 in.) to any vertical mass, or less than 300 mm (12 in.) from a vertical pavement edge, use the gauge manufacturer's correction procedure.

Overview

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There are two methods for determining in-place density of HMA. See agency requirements method selection.

- Direct Transmission
- Backscatter

Procedure

Direct Transmission

1. Maximum contact between the base of the
16 gauge and the surface of the material under test is critical. This mode cannot be used where the depth of the HMA is less than 33 mm (0.11').
2. Use the guide / scraper plate as a template and drill a hole to a depth of at least 7 mm (1/4 in.) deeper than the measurement depth required for the gauge.
3. Place the gauge on the prepared surface so that the probe can enter the hole. Lower the probe to the desired a test depth not to exceed the thickness of the lift of pavement being measured. Position the gauge by pulling it
17 towards the scaler / detector so that the probe is firmly against the side of the hole.
4. Take a one-minute test and record the wet density reading.
5. Rotate the gauge 90 degrees. Reseat the gauge by gently moving it side to side while pulling it towards the scaler / detector so that the probe is firmly against the side of the hole. Take another one-minute test and record the wet density reading.
6. The difference between the two one minute tests shall be less than 50 kg/m^3 (3 lb/ft^3). If not, then rotate the gauge another 90 degrees. Reseat the gauge by gently moving it side to side while pulling it towards the scaler / detector so that the probe is firmly against the side of the hole. Then take another one-minute test and record the wet density reading. Again

compare the readings. If difference between the second and third one minute tests is not less than 50 kg/m^3 (3 lb/ft^3) move to another test location.

Backscatter

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1. Maintain maximum contact between the base of the gauge and the surface of the material under test. Use filler material to fill surface voids. Spread a small amount of filler material over the test site surface and distribute it evenly. Strike off the surface with a straight edge to remove excess material.

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Nuclear gauge

2. Place the gauge on the test site. Using a crayon, (not spray paint) mark the outline or footprint of the gauge. Extend the probe to the backscatter position.
3. Take a one-minute test and record the wet density reading.
4. Rotate the gauge 90 degrees about the probe. Mark the outline or footprint of the gauge.

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5. Take another one-minute test and record the wet density reading.
6. If the difference between the two one minute tests is greater than 40 kg/m^3 (2.5 lb/ft^3), retest in both directions.

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Calculation of Results

The density reported for each test site shall be the average of the two individual one-minute wet density readings.

Percent compaction is determined by comparing the in-place wet density as determined by this method to the appropriate agency density standard. See appropriate agency policy for use of density standards.

Example:

Reading #1: 141.5 lb/ft^3

Reading #2 (90º): 140.1 lb/ft^3

Are the two readings within tolerance? (YES)

Reading Average: 140.8 lb/ft^3

Core correction: +2.1 lb/ft^3

Corrected Reading: 142.9 lb/ft^3

G_{mm} and Maximum Density from the FOP for AASHTO T 209:

G_{mm} = 2.466

153.5 lb/ft^3

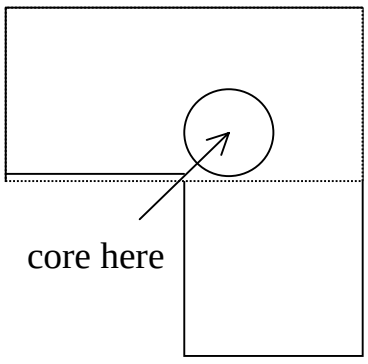
$$\frac{\text{Corrected Reading}}{\text{Maximum Density}} X 100 = \%\ \text{compaction}$$

$$\frac{142.9}{153.5} X 100 = 93.1\%$$

Correlation with Cores

Note 2: When density correlation with test method AASHTO T 166 is required, correlation of the nuclear gauge with pavement cores shall be made on the first day's paving (within 24 hours) or from a test strip constructed prior to the start of paving. Cores must be taken before traffic is allowed on the pavement.

1. Determine the number of cores required for correlation from the agency's specifications. Cores shall be located on the first day's paving or on the test strip. Locate the test sites in accordance with the agency's specifications. Follow the "Procedure" section above to establish test sites and obtain densities using the nuclear gauge.
2. Obtain a pavement core from each of the test sites. The core should be taken from the center of the nuclear gauge footprint. If direct transmission was used, locate the core at least 25 mm (1 in.) away from the edge of the drive pin-hole.



Core location inside gauge footprint

3. Determine the density of the cores by AASHTO
27 T 166, Bulk Specific Gravity of Compacted HMA Using Saturated Surface-Dry Specimens.

4. Calculate a correlation factor for the nuclear gauge reading as follows.

   a. Calculate the difference between the core density and nuclear gauge density at each test site to the nearest 1 kg/m^3 (0.1 lb/ft^3). Calculate the average difference and standard deviation of the differences for the entire data set to the nearest 1 kg/m^3 (0.1 lb/ft^3).

   b. If the standard deviation of the differences is
28 equal to or less than 40 kg/m^3 (2.5 lb/ft^3), the correlation factor applied to the nuclear density gauge reading shall be the average difference calculated above in 4.a.

   c. If the standard deviation of the differences is greater than 40 kg/m^3 (2.5 lb/ft^3), the test site with the greatest variation from the average difference shall be eliminated from the data set and the data set properties and
29 correlation factor recalculated following 4.a and 4.b.

   d. If the standard deviation of the modified data set still exceeds the maximum specified in 4.b, additional test sites will be eliminated from the data set and the data set properties and correlation factor recalculated following 4.a and 4.b. If the data set consists of less than five test sites, additional test sites shall be established.

Note 3: The exact method used in calculating the Nuclear Gauge Correlation Factor shall be defined by agency policy.

Note 4: The above correlation procedure must be repeated if there is a new job mix formula. Adjustments to the job mix formula beyond tolerances established in the contract documents will constitute a new job mix formula. A correlation factor established using this procedure is only valid for the particular gauge and in the mode and at the probe depth used in the correlation procedure. If another gauge is brought onto the project, it shall be correlated

using the same procedure. Multiple gauges may be correlated from the same series of cores if done at the same time.

Note 5: For the purpose of this procedure, a job mix formula is defined as the percent and grade of paving asphalt used with a specified gradation of aggregate from a designated aggregate source. A new job mix formula may be required whenever compaction of the wearing surface exceeds the agency's specified maximum density or minimum air voids.

Core Correlation Example:

Core results from T166:		Density results TM 8:		Difference:	
2338 kg/m^3	144.9 lb/ft^3	2295 kg/m^3	142.1 lb/ft^3	43 kg/m^3	2.8 lb/ft^3
2306 kg/m^3	142.8 lb/ft^3	2275 kg/m^3	140.9 lb/ft^3	31 kg/m^3	1.9 lb/ft^3
2314 kg/m^3	143.1 lb/ft^3	2274 kg/m^3	140.7 lb/ft^3	40 kg/m^3	2.4 lb/ft^3
2274 kg/m^3	140.7 lb/ft^3	2243 kg/m^3	138.9 lb/ft^3	31 kg/m^3	1.8 lb/ft^3
2343 kg/m^3	145.1 lb/ft^3	2319 kg/m^3	143.6 lb/ft^3	24 kg/m^3	1.5 lb/ft^3
2329 kg/m^3	144.2 lb/ft^3	2300 kg/m^3	142.4 lb/ft^3	29 kg/m^3	1.8 lb/ft^3
2322 kg/m^3	143.8 lb/ft^3	2282 kg/m^3	141.3 lb/ft^3	40 kg/m^3	2.5 lb/ft^3

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Average Difference: 34 kg/m^3 2.1 lb/ft^3

Standard Deviation: 6.5 kg/m^3 0.43 lb/ft^3

Report

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Results shall be reported on standard forms approved by the agency. Include the following information:

- Location of test and thickness of layer tested
- Mixture type
- Make, model and serial number of the nuclear moisture-density gauge
- Mode of measurement, depth, calculated wet density of each measurement and any adjustment data
- Standard density
- Percent compaction and/or percent air voids
- Name and signature of operator

Tips!

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– Check to make sure that base of gauge is clean prior to testing

– Shutter block and assembly are free of debris and operating correctly.

– Gauge is reading the proper position of the source rod when it is indexed, and that it has been seated correctly.

– When direct transmission is used, hole into which the source is lowered is at least 7 mm (1/4 in.) deeper than the indexed position of the source rod.

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– Surface is flat and the gauge does not rock.

– surface has been properly prepared using filler material

– Do not leave the gauge on a hot surface for a long time.

REVIEW QUESTIONS

1. Describe the calibration and standardization process.

2. What precautions must be taken in selecting a test location?

3. How do you determine percent compaction?

4. Describe the procedure for correlating results with pavement cores.

PERFORMANCE EXAM CHECKLIST

IN-PLACE DENSITY OF HOT MIX ASPHALT USING THE NUCLEAR MOISTURE-DENSITY GAUGE
FOP FOR WAQTC TM 8

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. Gauge turned on approximately 10 to 20 minutes before use?	_____	_____
2. Gauge calibrated and standard count recorded?	_____	_____
3. Test location selected appropriately (600 mm / 24 in. from vertical projections or 10 m (30 ft) from any other radioactive sources)?	_____	_____
4. Direct Transmission :		
a. Hole made 7 mm (1/4 in.) deeper than intended probe depth?	_____	_____
b. Gauge placed, probe extended, gauge pulled toward scaler / detector?	_____	_____
c. One-minute count taken; gauge rotated 90° reseated and another one-minute count taken?	_____	_____
d. Densities averaged?	_____	_____
e. If difference of the wet densities is greater than 50 kg/m^3 (3 lb/ft^3) gauge turned another 90° and retested?	_____	_____
5. Backscatter :		
a. Filler spread evenly over test site?	_____	_____
b. Excess filler material removed by striking off the surface?	_____	_____
c. Gauge placed on pavement surface and footprint of gauge marked?	_____	_____
d. Probe extended to backscatter position?	_____	_____
e. One-minute count taken; gauge rotated 90° reseated and another one-minute count taken?	_____	_____
f. Densities averaged?	_____	_____
g. If difference of the wet densities is greater than 40 kg/m^3 (2.5 lb/ft^3) retest conducted in both directions?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
6. Core correlation applied if required?	_____	_____
7. Percent compaction calculated correctly?	_____	_____

Comments: First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

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Examiner Signature _____WAQTC #:_____